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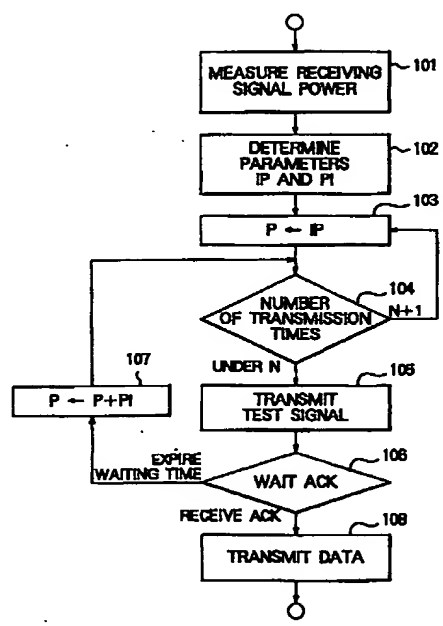
(54) Transmission power control method and communication device

(57) A receiving power is measured at a step 101. An initial value IP and an increment value PI for a transmission power are determined at a step 102 according to the receiving power measurement value. An expected transmission power P is set to the initial value IP at a step 103. At a step 104, it is determined whether the number of transmission times exceeds or not a predetermined number N. When the number of transmission times exceeds a predetermined number N, the operation goes back to the processing step 103. When the number of transmission times does not exceed a predetermined number of times N, a test signal is transmitted with the expected transmission power P at a step 105. After the transmission of the test signal, at a processing step 106, receipt acknowledge signal ACK from a receiving station is waited in a predetermined period of time. If no receipt acknowledge signal ACK is received in the predetermined period of time, the expected transmission power P is increased by the amount corresponding to PI at a step 107 and the operation goes back to the step 104. On the other hand, if the receipt acknowledge signal ACK is received in the predetermined period of time, the data which want to be transmitted is transmitted with the expected transmission power P at a step 108.

FIG. 3



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Description

[0001] The present invention relates to a transmission power control method and a communication device adapted from that method. More specifically, the present invention relates to a transmission power control method and a communication device for packet transmission or random access in communication devices using the Direct Sequence Code Division Multiple Access (DS-CDMA) architecture.

[0002] Random access communication systems using DS-CDMA include those derived from the TIA/EIA/IS-95-A standard for use in the United States, "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", May 1995. The system set forth in this standard is herein referred to an IS-95 system. For transmission of data in a random access manner, a communication device using the IS-95 system transmits the data repeatedly with increased transmission power until it receives a data acknowledge signal (ACK) from a receiving station indicating successful receipt of the transmitted data. At the time when the transmission power reaches a predetermined maximum value, the transmission power is reset to an initial value to continue transmission. The initial value for the transmission power is determined at the transmitting station depending on received power of signals transmitted from the receiving station.

[0003] The packet transmission supplies data in some cases as in the random access transmission. Two control systems have been proposed for the packet transmission in TRANSACTIONS OF THE IEICE, Japan 1997, pages 420 and 422. The former one is referred herein as a control system A and the latter a control system B. These systems employ different power control methods at the beginning of a transmission. The transmission power is controlled in either system according to control signals supplied from a receiving station after the second time slots of the transmission. Transmission begins with an initial value for the transmission power determined depending on the received signal power in the control system A. The receiving station supplies more control signals during the first time slot than during the second and later time slots. On the other hand, the control system B involves exchanging reservation packets between a transmitting station (sender) and a receiving station (receiver). The receiving station determines the initial transmission power of the transmitting station depending on the received signal power of the reservation packet and then notifies the transmitting station of the initial transmission power.

[0004] Conventional transmission power control methods using the above-mentioned IS-95 system transmit data several times with the power not being adjusted properly. Thus the transmission interferes significantly with other communication channel(s) that use(s) the same frequency range as the communication device in question. It is understood that the larger the transmission power the more significantly the other channel(s) is/are interfered. Reduction of the transmission power may be a solution to this problem. However, smaller transmission power results in a longer period required for repeated transmission of data before it is received correctly. This means that the other channel(s) is/are interfered for a longer period.

[0005] As apparent from the above, once the initial value for the transmission power and an incrementing amount for the transmission power are determined, the transmission power is increased, while reset to the initial value a number of times, until the transmitting station receives the data acknowledge signal (ACK) from the receiving station. Accordingly, data are transmitted an increased number of times, interfering with other channel(s) for a longer period. Briefly, the above-mentioned prior arts have no mechanism to adjust the transmission power properly. This would be a cause of such a longer interference period.

[0006] In addition, the amount of interference also increases due to the repeated transmission of data. In the above-mentioned prior arts, data are transmitted at the increased number of times until the transmission power becomes a proper level. The amount of interference increases as well with the increased number of transmissions.

[0007] The conventional transmission power control methods using the above-mentioned IS-95 system waste much power and thus dissipate a significant amount of power, sacrificing battery lifetime. The above-mentioned control system A begins data transmission after an initial value for the transmission power is determined depending on the received signal power. With an improper initial value, other communication channel(s) that use(s) the same frequency band range can be interfered.

[0008] The above-mentioned control system B has a problem in determining the transmission power of reservation packets. More specifically, excessively large power for reservation packets may cause interference with other communication channel(s), while reservation packets with smaller power may fail to be received by a receiving station and then they will be retransmitted. In addition, the dynamic range that is used to indicate the initial transmission power should be sufficient.

[0009] An object of the present invention is to provide a transmission power control method and a communication device that transmit no signal with improper power, eliminate wasteful transmission, and reduce interference, if any, with other communication channel(s).

[0010] A transmission power control method according to the present invention comprises: measuring received power of signals transmitted from a receiving station; determining an initial value of transmission power according to a measurement value of the received power; and initiating transmission of a signal with the transmission power set to the determined initial value. In this method, during the transmission, the

transmission power is increased until the receiving station returns a receipt acknowledge signal to the transmitting station and the transmitting station detects the receipt acknowledge signal. The initial value is decreased when the received power in the current communication is larger than that in the previous communication, while the initial value is increased when the received power in the current communication is smaller than that in the previous communication. The initial value is changed at a smaller rate in increase than in decrease.

[0011] A communication device according to the present invention comprises: a receiving unit for receiving signals from a receiving station; a power measuring unit for measuring power of the received signals; a acknowledge signal detection unit for detecting a receipt acknowledge signal in the received signals; an initial value determining unit for determining an initial value of transmission power according to the received signal power measured by the power measuring unit such that the initial value is decreased when the power of received signals in the current communication is larger than that in the previous communication, while it is increased when the power of received signals in the current communication is smaller than that in the previous communication, and such that the initial value is changed at a smaller rate in increase than in decrease; and a transmitting unit that initiates transmission of data with the initial value of transmission power determined by the initial value determining unit, increasing gradually the transmission power until being notified of detection of the receipt acknowledge signal.

[0012] In the present invention, the initial value of transmission power is carefully controlled. The initial value is decreased when the received power of signals in the current communication is larger than that in the previous communication. Any interference with other communication channel(s) can thus be reduced. On the other hand, the initial value is increased when the received power of signals in the current communication is smaller than that in the previous communication. Because the increase rate of transmission power is set smaller than the decrease rate, any interference with other communication channel(s) can also be reduced.

[0013] According to the present invention, an increment value of transmission power is made larger, when the measured value of the received signal power in the current communication is smaller than that in the previous communication, than that when the measured value of the received signal power in the current communication is larger than that in the previous communication.

[0014] In the present invention, the increment value of transmission power is carefully controlled. Because the initial value of transmission power in the present invention is increased in a relatively small amount, a larger number of times will be required for updating the power to a sufficient level for receiving if the increment value is the same. With this respect, the increment value is made large when the measured value of the received signal power in the current communication is smaller than that in the previous communication. This makes possible to reduce the number of times required for updating the transmission power to a sufficient level for receiving.

[0015] According to the present invention, a test signal is transmitted until the acknowledge signal detection unit detects a receipt acknowledge signal. In response to detection of a receipt acknowledge signal, the data which want to be transmitted are transmitted with the transmission power at the time of detecting the receipt acknowledge signal.

[0016] Furthermore, in the present invention, the test signal is used to obtain the desired transmission power. The test signal may be a signal that lasts for a shorter period than the object data . This allows reduction of any interference with other communication channel(s).

Fig. 1 is a time characteristic diagram that indicates state of data transmission for use in describing operation of a prior art;

Fig. 2 is a block diagram of a communication device according to a first embodiment of the present invention;

Fig. 3 is a flow chart for use in describing operation of the communication device according to the first embodiment of the present invention;

Fig. 4 is a time characteristic diagram that indicates state of data transmission for use in describing operation of the communication device according to the first embodiment;

Fig. 5 is a characteristic curve for a transmission power initial value for use in describing operation of the communication device according to the first embodiment;

Fig. 6 is a time characteristic diagram that indicates state of data transmission for use in describing operation of the communication device according to the first embodiment;

Fig. 7 is a characteristic curve for a transmission power increment value for use in describing operation of the communication device according to the first embodiment;

Fig. 8 is a time characteristic diagram that indicates state of data transmission for use in describing operation of the communication device according to the first embodiment; and

Fig. 9 is a block diagram of a communication device according to a second embodiment of the present invention.

[0017] A first embodiment of the present invention is described in detail with reference to the drawings. Referring to Fig. 2, a communication device according to an embodiment of the present invention comprises a receiving antenna 24, a demodulation circuit 23, an ACK detection circuit 25, a receiving power measure-

ment circuit 26, an initial value determining circuit 16, an increment value determining circuit 17, a transmission power control circuit 15, a timer 18, a modulation circuit 13, and a transmission antenna 14.

[0018] The receiving power measurement circuit 26 measures power of a signal (receiving power) received by the demodulation circuit 23. The ACK detection circuit 25 determines whether a receipt acknowledge signal ACK is present or not in an output of the demodulation circuit 23. The initial value determining circuit 16 determines a transmission power initial value IP according to a measurement value of the received signal power supplied from the receiving power measurement circuit 26. The initial value determining circuit 16 increases the transmission power initial value IP when the received signal power in the current communication is smaller than that in the previous communication. On the other hand, the initial value determining circuit 16 decreases the transmission power initial value IP when the received signal power in the current communication is larger than that in the previous communication. The initial value determining circuit 16 determines the transmission power initial value IP such that the transmission power initial value IP is changed at a smaller rate in increase than in decrease. The increment value determining circuit 17 makes an increment value PI larger when the received signal power in the current communication is smaller than that in the previous communication, than that when the received signal power in the current communication is larger than that in the previous communication. The transmission power control circuit 15 switches transmission signals between test signals and the data which want to be transmitted. The transmission power control circuit 15 instructs beginning/ending of data transmission as well as the transmission power to the modulation circuit 13. The modulation circuit 13 transmits, according to the instruction from the transmission power control circuit 15, the test signal with the transmission power which is increased gradually from the transmission power initial value IP. In response to detection of the receipt acknowledge signal ACK by the ACK detection circuit 25, the transmission power control circuit 15 instructs to transmit the object data with the transmission power at that time of detection. The test signal used is a known signal that lasts for a shorter period than the object data.

[0019] Next, operation of the communication device according to this embodiment is described with reference to Fig. 3. At a processing step 101, the receiving power measurement circuit 26 measures received power of a signal transmitted from a receiving station. At a processing step 102, the initial value determining circuit 16 and the increment value determining circuit 17 determine the initial value IP and the increment value PI for the transmission power, respectively, according to the receiving power measurement value. At a processing step 103, the transmission power control circuit 15 sets expected transmission power P to the initial value IP. At a processing step 104, the transmission power control circuit 15 determines whether the number of transmission times exceeds or not a predetermined number N. When the number of transmission times exceeds a predetermined number N, the operation goes back to the processing step 103. When the number of transmission times does not exceed a predetermined number N, the modulation circuit 13 transmits the test signal with the expected transmission power P (processing step 105). After the transmission of the test signal, at a processing step 106, the transmission power control circuit 15 waits for receiving the receipt acknowledge signal ACK from the receiving station for a predetermined period of time that is set by the timer 18. If no receipt acknowledge signal ACK is received in the predetermined period of the at the processing step 106, the transmission power control circuit 15 increases the expected transmission power P by the amount corresponding to PI (processing step 107) and the operation goes back to the processing step 104. On the other hand, if the receipt acknowledge signal ACK is received in the predetermined period of time at the processing step 106, the object transmission data is transmitted with the expected transmission power P (processing step 108).

[0020] Fig. 4 is a view illustrating the transmission power as a function of time in the data transmission by using the above-mentioned transmission power control. The short test signals are transmitted before the transmission of the object data. The first test signal is transmitted with the transmission power of the initial value IP. The transmission power control circuit 15 waits for the receipt acknowledge signal ACK for a time period of TA after the transmission of the test signal. If no receipt acknowledge signal ACK is received in the time period of TA, the next test signal is transmitted with the transmission power increased by the amount corresponding to PI. Then, the transmission power control circuit 15 waits for the receipt acknowledge signal ACK for an additional time period of TA after the transmission of the second test signal. This transmit-and-wait cycle is repeated with the transmission power increased gradually. In response to receiving the receipt acknowledge signal ACK, the object transmission data is transmitted with the transmission power at that time. If the transmission power is increased excessively due to no receipt acknowledge signal ACK is received, the transmission power is reset to the initial value IP as shown in Fig. 8. The test signal is again transmitted after the transmission power is reset to the initial value IP.

[0021] The initial value IP of the transmission power is determined depending on the change in receiving power of the signal from the receiving station. Fig. 5 shows this relationship. By comparing data transmission conditions in the current communication with those in the previous communication, the initial value determining circuit 16 decreases the initial value IP depending on the amount of increase of the receiving power

when the receiving power is increased. It is noted that the increase of the receiving power is due to reduced signal attenuation between the receiving station and the transmitting station. Communication can be made with a smaller transmission power. When the receiving power becomes small, the initial value IP is increased by a smaller amount than the amount corresponding to the receiving power reduction. The decrease of the receiving power is considered to be due to becoming signal attenuation larger between the receiving station and the transmitting station. However, the larger transmission power may interfere more and more with other communication channel(s) that use(s) the same frequency band range. Thus careful operation is required to increase the transmission power.

[0022] As shown in Fig. 5, the initial value determining circuit 16 does not change the initial value IP when the transmission power is reduced in a certain range. The initial value determining circuit 16 makes the adjustment value of the initial value IP smaller than the reduction mount of the receiving power when the receiving power is reduced relatively significantly. An adjustment value characteristic for the initial value IP obtained when the receiving power decreases may be any one of characteristics as long as the adjustment value is smaller than the reduction mount of the receiving power.

[0023] Fig. 6 is a view illustrating data transmission that requires a larger transmission power as compared with the case shown in Fig. 4. As shown in Fig. 5, the transmission power initial value IP is not so increased as the reduction of the receiving power. Therefore, the test signals will be transmitted larger number of times to achieve the desired transmission power, if the increment value of the transmission power is the same. In such a case, that problem is solved by initiating the transmission of the test signal earlier.

[0024] As for the case shown in Fig. 6, the time duration for the test signals can be reduced by means of increasing the increment value PI as shown in Fig. 7, while decreasing the number of times to transmit the test signals. In Fig. 7, the increment value PI is set larger when the receiving power is reduced. In Fig. 7, the characteristic is expressed as a multi-stage step function but any other characteristics may be used as long as the increment value PI is increased when the receiving power is reduced.

[0025] Fig. 9 is a block diagram showing an embodiment where the communication device according to the present invention is applied to spread-spectrum communication. Now, a device shown in Fig. 9 is described in comparison with the one in Fig. 2. The modulation circuit 13 in Fig. 2 is divided into three components in Fig. 9: a frame generation circuit 10, a spread circuit 11, and a radio transmission circuit 12. The demodulation circuit 23 in Fig. 2 is divided into two components in Fig. 9: a radio receiving circuit 22 and a despread circuit 21. The frame generation circuit 10 arranges either the object transmission data or the test signals with synchronization signals and control information in time axis. The spread circuit 11 converts an input signal into a wide-band signal according to spread spectrum communication. The de-spread circuit 21 turns the converted wide-band signal into an original form. The radio transmission circuit 12 modulates an output of the spread circuit 11 to have a radio frequency. The radio receiving circuit 22 demodulates the received radio signal. The transmission control circuit 19 is a combination of the transmission power control circuit 15, the initial value determining circuit 16, and the incremental value determining circuit 17. The frame separation circuit 20 separates the signals arranged in time axis.

[0026] When the transmission data is an audio signal, there is no data to be transmitted in a silent duration. The amount of data to be transmitted is thus significantly small. A modification of the present invention includes such a case where the transmission of the test signal is started after enough amount of data to be transmitted are accumulated. This configuration contributes to reduction of interference with other communication channel(s) that use(s) the same frequency band range.

[0027] As described above, according to the present invention, the initial value of the transmission power is controlled depending on the receiving power. More specifically, the transmission power initial value is decreased when the receiving power in the current communication is larger than that in the previous communication. On the other hand, the transmission power initial value is increased when the receiving power in the current communication is smaller than that in the previous communication. In this event, the transmission power initial value is changed at a smaller rate in increase than in decrease. Such control of the transmission power initial value allows proper transmission power settings, which results in reduction of interference with other communication channel(s) that use(s) the same frequency band range as well as reduction of the power required for the transmission.

[0028] In addition, according to the present invention, the number of update times before the transmission power reaches the desired value can be reduced by means of increasing the increment value of the transmission power when the transmission power initial value is increased in a relatively small amount. This also contributes to the reduction of interference with other communication channel(s).

[0029] Furthermore, according to the present invention, short test signals are transmitted before transmission of the object data. The object data is transmitted after the transmission power is determined, reducing interference with other communication channel(s).

Claims

1. A transmission power control method comprising the steps of:

measuring power of a receiving signal transmitted from a receiving station;
determining an initial value of transmission power according to a measurement value of the receiving power; and
initiating the transmission of a signal with the transmission power set to the determined initial value; wherein, during the transmission,
the transmission power is increased until a receiving station returns a receipt acknowledge signal and the transmission station detects the receipt acknowledge signal;
the initial value is decreased when the receiving power in the current communication is larger than that in the previous communication, while the initial value is increased when the receiving power in the current communication is smaller than that in the previous communication, and the initial value is changed at a smaller rate in increase than in decrease.

2. A transmission power control method as claimed in Claim 1, wherein an increment value of the initial transmission power is determined larger when the measurement value of the receiving power in the current communication is smaller than that in the previous communication, than when the measurement value of the receiving power in the current communication is larger than that in the previous communication.

3. A transmission power control method comprising the steps of:

measuring power of a receiving signal transmitted from a receiving station;
determining an initial value and an increment value of a transmission power according to a measurement value of the receiving power;
setting expected transmission power as the initial value;
determining whether the number of transmissions exceeds or not a predetermined threshold value to return to the step of setting the expected transmission power as the initial value when the number of transmissions exceeds the predetermined threshold value;
transmitting a test signal with the expected transmission power when the number of transmissions are not larger than the predetermined threshold value;
waiting, for a certain period of time, a receipt acknowledge signal from the receiving station; and
increasing, when no receipt acknowledge signal is detected in the certain period of time, the expected transmission power by the amount corresponding to the increment value to return to the step of determining the number of transmissions, and transmitting, when the receipt acknowledge signal is detected in the certain period of time, data that want to be transmitted, with the expected transmission power.

4. A communication device comprising:

receiving means for receiving a signal transmitted from a receiving station as a receiving signal;
receiving power measurement means for measuring receiving power of the receiving signal to produce a receiving power measurement value;
receipt acknowledge signal detection means for detecting a receipt acknowledge signs from an output of said receiving means;
initial value determining means for determining an initial value of transmission power according to the receiving power measurement value supplied from said receiving power measurement means such that said initial value determining means decreases the initial value of the transmission power when receiving power in the current communication is larger than that in the previous communication, while the initial value is increased when the receiving power in the current communication is smaller than that in the previous communication, and the initial value is changed at a smaller rate increase than in decrease ; and
transmitting means that initiates transmission of data with the initial value of the transmission power determined by said initial value determining means, and increases gradually the transmission power until said transmitting means is notified of detection of the receipt acknowledge signal.

5. A spread-spectrum communication device comprising:

receiving means for receiving a signal transmitted from a receiving station as a receiving signal;
receiving power measurement means for measuring power of the receiving signal to produce a receiving power measurement value;
receipt acknowledge signal detection means for detecting a receipt acknowledge signal from an output of said receiving means;
initial value determining means for determining an initial value of transmission power according to the receiving power measurement value supplied from said receiving power measurement means such that said initial value determining means decreases the initial value of the

transmission power when the receiving power in the current communication is larger than that in the previous communication, while the initial value is increased when the receiving power in the current communication is smaller than that in the previous communication, and the initial value is changed at a smaller rate increase than in decrease ; and

transmitting means that initiates transmission of data with the initial value of the transmission power determined by said initial value determining mans, and increases gradually the transmission power until said transmitting means is notified of detection of the receipt acknowledge signal .

6. A communication device as claimed in Claim 4 or 5, wherein said transmitting means transmits test signal until said receipt acknowledge signal detection means detects the receipt acknowledge signal, and transmits, in response to the detection of the receipt acknowledge signal, data which want to be transmitted, with the transmission power at the time of the detection.

7. A communication device as claimed in Claim 6, wherein said transmitting means begins transmission of the test signal at an earlier timing when the initial value of the transmission power is increased.

8. A communication device as claimed in Claim 6 or 7, wherein an increment value of the transmission power used by said transmitting means is determined according to the receiving power measurement value supplied from said receiving power measurement means, and wherein said communication device further comprises increment value determining means for determining a larger increment value when the receiving power in the current communication is smaller than that in the previous communication, than when the receiving power in the current communication is larger than that in the previous communication.

FIG. 1
PRIOR ART

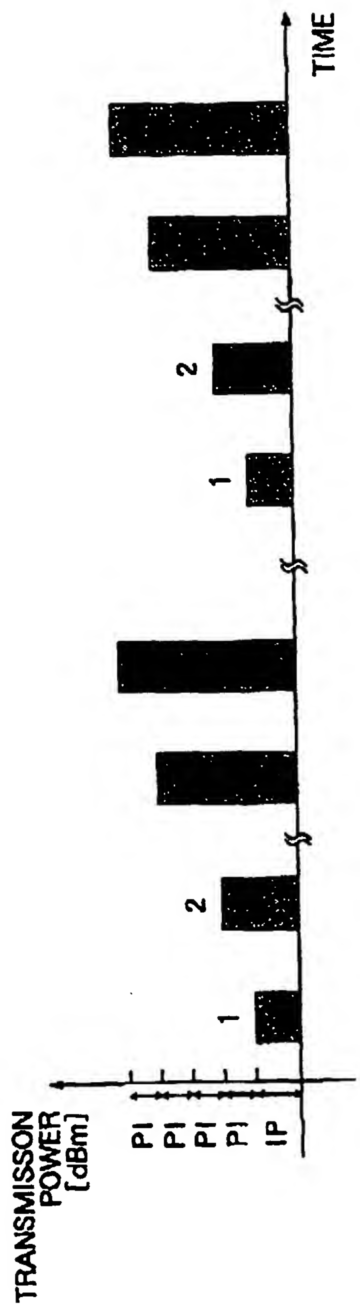


FIG. 2

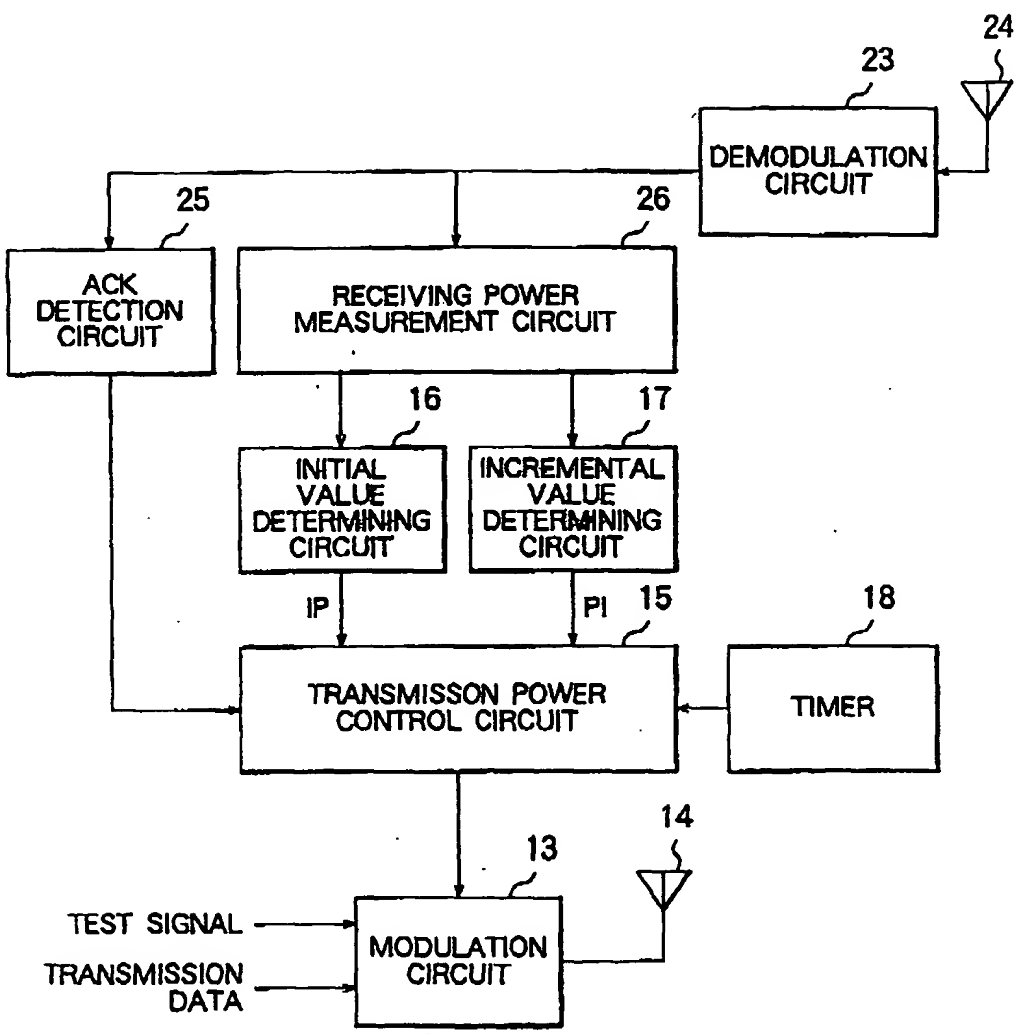

24
23
DEMODULATION CIRCUIT
25
26
ACK DETECTION CIRCUIT
RECEIVING POWER MEASUREMENT CIRCUIT
16
17
INITIAL VALUE DETERMINING CIRCUIT
INCREMENTAL VALUE DETERMINING CIRCUIT
IP
PI
15
18
TRANSMISSON POWER CONTROL CIRCUIT
TIMER
14
13
TEST SIGNAL
TRANSMISSION DATA
MODULATION CIRCUIT

FIG. 3

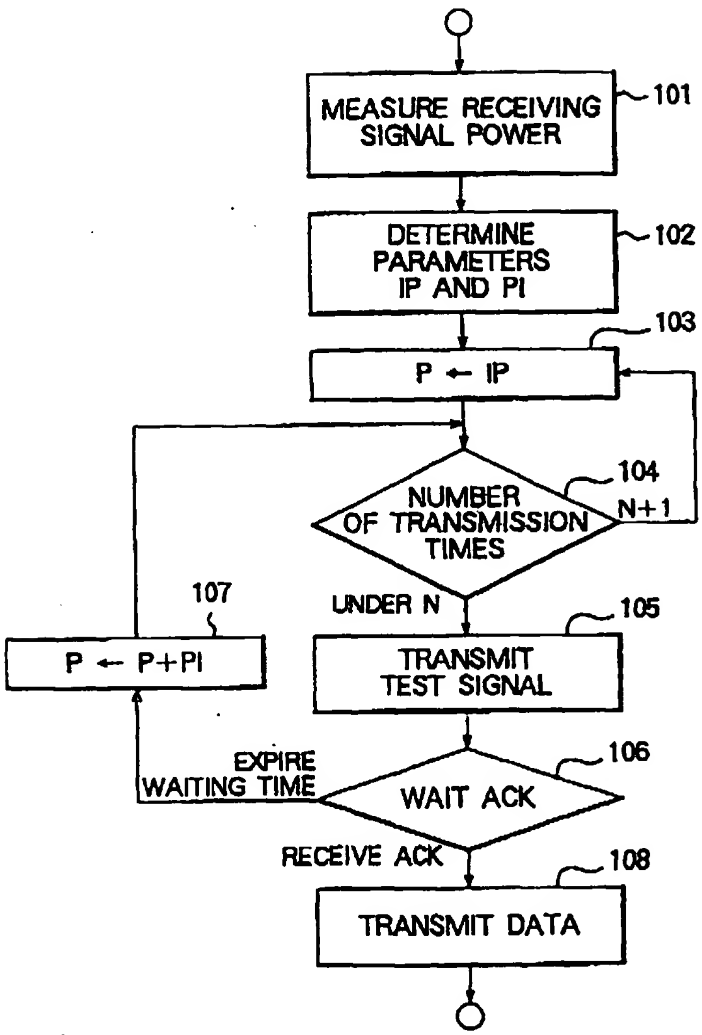

MEASURE RECEIVING SIGNAL POWER
101
DETERMINE PARAMETERS IP AND PI
102
P ← IP
103
NUMBER OF TRANSMISSION TIMES
104
N+1
UNDER N
TRANSMIT TEST SIGNAL
105
107
P ← P+PI
EXPIRE WAITING TIME
WAIT ACK
106
RECEIVE ACK
TRANSMIT DATA
108

FIG. 4

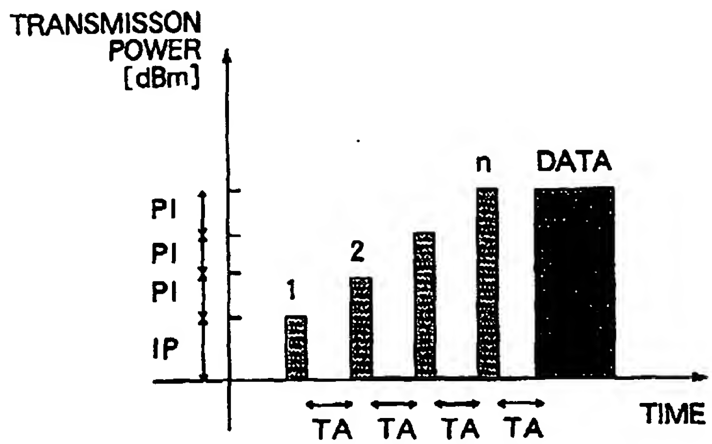

TRANSMISSON
POWER
[dBm]
n
DATA
PI
PI
PI
IP
1
2
TA
TA
TA
TA
TIME

FIG. 5

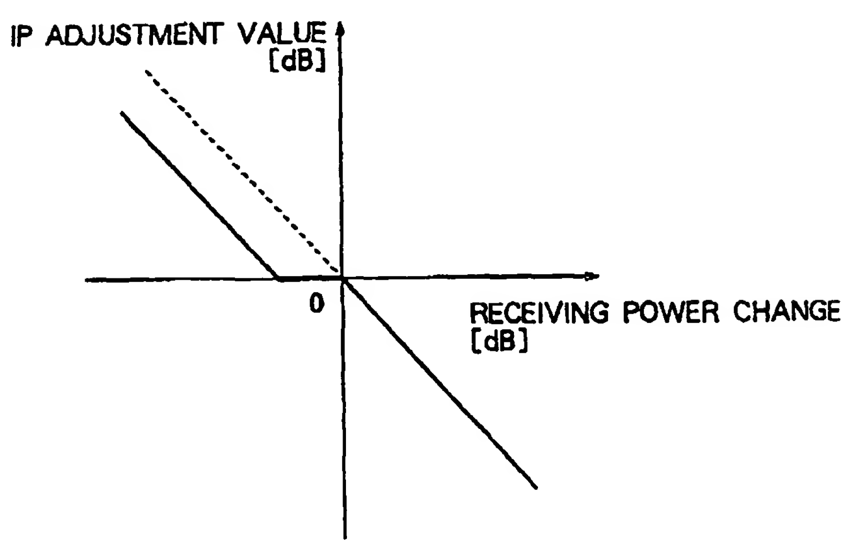

IP ADJUSTMENT VALUE
[dB]
0
RECEIVING POWER CHANGE
[dB]

FIG. 6

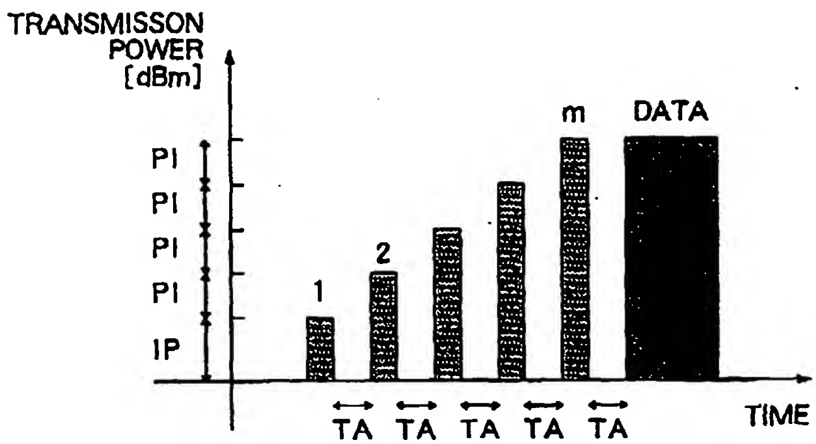

TRANSMISSON
POWER
[dBm]
m
DATA
PI
PI
PI
PI
1
2
IP
TA
TA
TA
TA
TA
TIME

FIG. 7

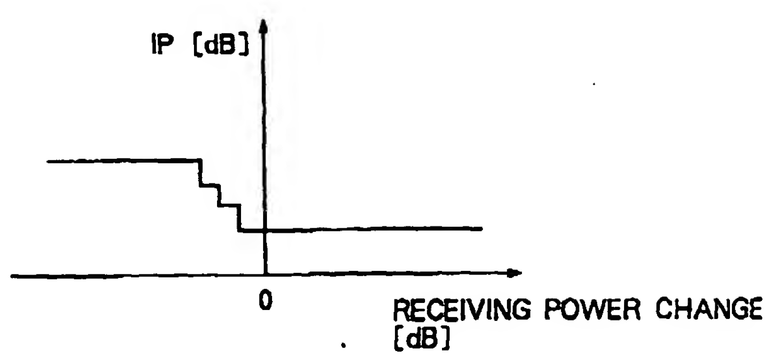

IP [dB]
0
RECEIVING POWER CHANGE
[dB]

FIG. 8

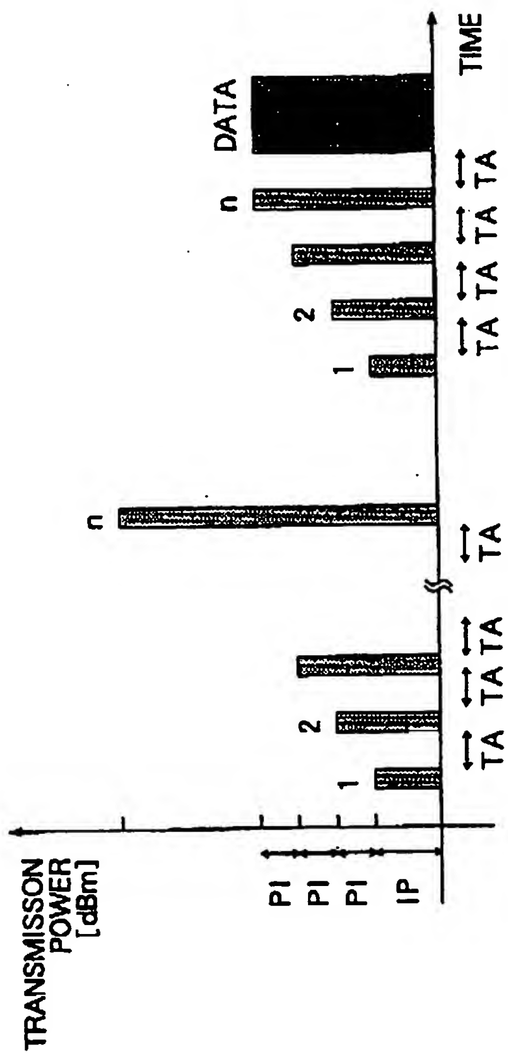
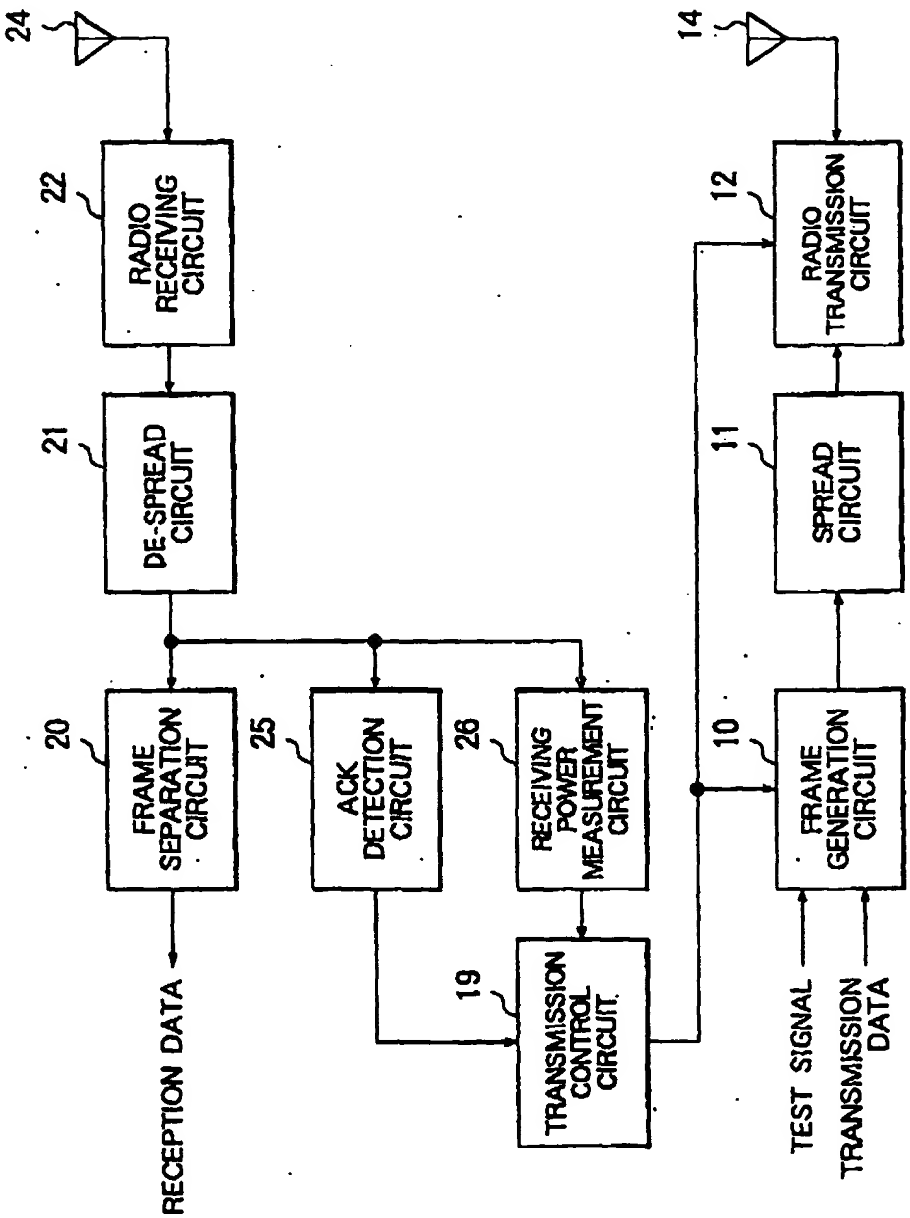

TRANSMISSON POWER [dBm]
PI
PI
PI
IP
1
2
n
TA
TA
TA
TA
1
2
n
TA
TA
TA
TA
DATA
TIME

FIG. 9


24
22
RADIO RECEIVING CIRCUIT
21
DE-SPREAD CIRCUIT
20
FRAME SEPARATION CIRCUIT
25
ACK DETECTION CIRCUIT
26
RECEIVING POWER MEASUREMENT CIRCUIT
19
TRANSMISSION CONTROL CIRCUIT
RECEPTION DATA
14
12
RADIO TRANSMISSION CIRCUIT
11
SPREAD CIRCUIT
10
FRAME GENERATION CIRCUIT
TEST SIGNAL
TRANSMISSION DATA